Resource Department

Geophysics Department

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The ESD Geophysics Department is driven by two primary objectives. One is to advance the state of the art in new technologies for extracting subsurface properties, including fluid properties, saturation, porosity, pore pressure, permeability, and *in situ* stress from laboratory and/or field measurements at the earth surface or in boreholes. These new methodologies incorporate information obtained using a variety of data, including geophysical data such as seismic, electromagnetic (EM), electrical, seismo-electric, gravity, ground-penetrating radar (GPR), geomechanical (tilt, deformation), fluid flow (pressure), and satellite (GPS). The other, equally important objective is the development of technologies for subsurface resource extraction, including seismically enhanced oil recovery, geomechanics-based subsurface permeability enhancement, and unconventional hydrocarbon resource development, such as gas hydrate and tight gas.

Fundamental and applied research carried out in support of these objectives include laboratory rock physics and pore-scale imaging studies, field geophysical-imaging hardware development, theory development, computational geophysics as well as geomechanical modeling and analysis, together with imaging and inversion (both deterministic and stochastic) algorithm and code development. Motivating this research is the increasing need for direct imaging of fluid saturations, pore pressures, and permeability in the subsurface for energy production, environmental remediation, carbon management, and nuclear waste disposal purposes, and to do so in the presence of anisotropy and multiscale heterogeneities.

SCIENTIFIC RESEARCH AREAS

The department is organized into five scientific research areas, led by the indicated Research Area Leaders:

- Computational Geophysics *(Don Vasco)*
- Rock Physics and Coupled Dynamics *(Seiji Nakagawa)*
- Hydrogeophysics & Biogeophysics *(Susan Hubbard)*
- Advanced Geophysical Instrumentation *(Tom Daley)*
- Geomechanics *(Jim Berryman)*

The primary purpose of these research areas is to advance the science that will enable new high-resolution methods for extracting subsurface properties and process-related information from geophysical, geomechanical, fluid-flow, and satellite data.

Computational Geophysics *(Don Vasco)*

The focus of this research area is to develop efficient 3-D numerical codes for modeling seismic wave propagation and electromagnetic wave propagation and diffusion. The challenge is to develop accurate and efficient computer codes capable of modeling the seismic and electromagnetic response of complex geologic structures (i.e., structures that may contain anisotropy or multiscale heterogeneities in the form of fractures, faults, and/or patchy saturation). A variety of methods, including boundary integral equation, global matrix, finite difference, spectral element, discrete element, and asymptotic ray methods, are currently being developed for high-performance parallel computing frameworks. These codes will serve as the *computational engines* for the next generation of modeling-based deterministic and stochastic inversion algorithms. This research is performed using the supercomputers at the National Energy Research Scientific Computing Center (NERSC) at Berkeley Lab, and the PC cluster maintained by the Center for Computational Seismology (CCS) within ESD.

Rock Physics and Coupled Dynamics *(Seiji Nakagawa)*

The connections between a geophysical observable (such as seismic velocities and attenuation, electrical conductivity, and dielectric constant) and rock properties (such as porosity, permeability, and fluid saturation) are provided by rock-physics measurements and/or theoretical understanding. Rock-properties measurement efforts are carried out at our Rock and Soil Physics Lab. This facility has electronics instrumentation and mechanical equipment needed to perform a variety of geophysical measurements, including seismic, electrical, electromagnetic, and fluid flow, under low to moderate confining pressures. Experiments requiring detailed information about the porous microstructure and fluid saturations at the pore level are carried out using our x-ray computed tomography (CT) scanner in the Rock Imaging Lab, or using the focused ion beam (FIB) located at Berkeley Lab's National Center for Electron Microscopy. Other facilities at the Berkeley Lab Advanced Light Source (ALS) are also used for microtomography of geologic materials, including fluid-infiltrated porous media.

The primary focus of our laboratory efforts is towards increasing our experimental knowledge base for geophysical properties of rocks and sediments that are either not well described by conventional rock-physics understanding (e.g., poorly consolidated sands and clays, gas hydrates, fractured rock) or have yet to be fully exploited (e.g., seismic attenuation, seismo-electric response). Complementary theoretical efforts are also under way to explore the dynamics of poroelastic and seismoelectric responses in rock that contains one or multiple fluid phases.

Hydrogeophysics & Biogeophysics *(Susan Hubbard)*

Research in this area combines the disciplines of geophysics, hydrogeology, and biogeochemistry to develop new approaches for characterizing shallow subsurface properties and for monitoring complex processes associated with natural or induced subsurface perturbations. This interdisciplinary field is unique in the level of fusion among hydrobiogeochemical-geophysical data sets, the incorporation of complex petrophysical models, and the application of emerging stochastic inversion techniques geared toward shallow subsurface systems. The majority of the research performed in this area is focused on developing and testing methods that will improve our ability to manage and monitor water resources and environmental contaminants.

Advanced Geophysical Instrumentation *(Tom Daley)*

The focus of this research area is the development of innovative geophysical hardware and methodologies for subsurface imaging and monitoring. Efforts that are currently under way include the development of passive and active seismi systems for utilizing microhole technology, an optimum electromagnetic system for detecting and identifying unexploded ordnance, and a novel electromagnetic imaging system (for environmental applications) that operates in the frequency band between electromagnetic diffusion and wave propagation. Additionally, development continues on a small-diameter high-frequency orbital-vibrator shear source for crosswell and single-well seismic imaging applications, high-resolution tomographic (radar and seismic) tools, and micro-earthquake monitoring systems.

Geomechanics *(Jim Berryman)*

This research area is concerned with the development of new computational and analytical tools for predicting stress-induced changes in transport properties, rock-formation fracturing, and fault slip resulting from fluid injection, fluid withdrawal, and thermal loading. Of particular interest is the development of new computational geomechanics-based inverse methods for estimating subsurface fracturing and fluid movement, for predicting the seismic response resulting from fluid injection into fractured rock, and for relating seismic wave propagation velocities to these properties for purposes of reservoir monitoring and/or hydrocarbon resource localization.

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